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TM-1037
1502.000

# DESIGN OF AN ELECTRON COOLING ACCUMULATOR RING FOR THE FERMILAB ANTIPROTON SOURCE

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April 1981

This report describes the design of a large-acceptance storage ring which can be added onto a planned booster-size stochastic cooling ring and can be used as an accumulator ring for antiproton collision. The design parameters of this ring have been chosen so as to allow efficient electron cooling to be carried out in a range between 200 and 450 MeV, and possibly as high as 1 GeV antiproton energy(1).

The overall design of this ring is very similar to that of the present electron cooling ring(2) and has essentially the same constraints. The intended mode of operation is to inject $\bar{p}$'s from the precooler into the accumulator and then momentum displace the injected beam into a stack which will be electron cooled. Thus, the ring needs a straight section appropriate for injection and extraction and another one for cooling. The parameters for injection and extraction are large horizontal dispersion and small beam sizes. The length of this straight section need not be too great. The cooling straight section, on the other hand, should be quite long, have no dispersion, and have $\bar{p}$ beam sizes matched to electron beam sizes, approximately an inch in radius. One would like to have as large a percentage of the circumference as possible to be filled with electron cooling, subject to several considerations. The expense, etc., of the cooling system, as well as the non-linear end effects of solenoid, torroids, and electron beam on the $\bar{p}$'s effectively limit the number of cooling systems to one, and the beam size variation through the cooling region limits the length of that region. The desire for some superperiodicity produces at least a four-sided figure. The final design of this ring, then, is generally the same as the present cooling ring. It is a racetrack design having two long straight sections, one of which will be used for electron cooling, and two short straight sections for injection and extraction, and for such functions as a beam dump, etc. The main difference between this ring and the present one is in the overall circumference, percent of machine used for cooling and maximum energy of the ring. The ring has a circumference of some 203 m, and will have 10 m of electron cooling as opposed to 135 m and 5 m of cooling in the present experiment. The structure and lattice parameters for this ring are listed in Table I, and the lattice functions are plotted in Figure 1. Horizontal and vertical aperture requirements are shown in Figures 2 and 3.

The ring has been designed to use the same type magnets as we are using in present electron cooling ring. A total of 44 4-foot dipoles and 48 2-foot quadrupoles with sizes and apertures as given in reference 2 are needed. In addition, two 2-foot quads with a good field region of 30 cm are required for injection. The totals given here include six standard quadrupoles required for transfer to and from the precooler ring. Finally, two 5-foot kickers with a movable shutter and one 5-foot c-magnet are required for injection and extraction. These need to reach fields of 380 gauss and 2.4 gauss respectively at an antiproton energy of 450 MeV.

(1) W. Kells et al., "Electron Cooling for the Fermilab $\bar{p}$ Source", Particle Accelerator Conference, March 1981, to be published.

(2) "Fermilab Electron Cooling Experiment, Design Report", Fermilab, August 1978.

TABLE I

1. General

| | |
|---|---|
| Energy | 200 MeV - 1.0 GeV |
| Corresponding bend field | 2.35 KG - 6.17 KG |
| Magnetic bend radius ($\rho$) | 9.17 m |
| Radius | 32.35 m |
| | = 36/1113 MR radius |
| Revolution time | 1197 - 775 nsec |
| Superperiodicy | |
| without electron beam | 2 |
| with electron beam | 1 |
| Focusing structure | Separated function |
| | FODO normal cell |
| Nominal working point | $\nu_H$ 4.102 |
| | $\nu_V$ 5.390 |
| | $\gamma_T$ 4.084 |
| Natural chromaticity | $\xi_H$ -7.410 |
| | $\xi_V$ -6.409 |

2. Magnets

| | |
|---|---|
| Number of dipoles | 44 |
| length of dipoles | 48.00" |
| effective length of dipoles | 51.52" |
| Number of quadrupoles | 44 |
| length of quadrupoles | 24.00" |
| effective length of quadrupoles | 26.64" |

Quadrupole gradients at 1.0 GeV

| | |
|---|---|
| QF | 28.70 kG/m |
| QD | -26.47 |
| Q1 | -37.89 |
| Q2 | 43.82 |
| Q3 | -9.90 |
| Q9 | 22.69 |
| Q10 | -28.84 |
| Q11 | 15.07 |

3. Structure

A. Curved section

| Elements in curved section | | Length |
|---|---|---|
| Dipole | (B) | 4 ft. |
| Quadrupole | (Q) | 2 ft. |
| Drift space | (0) | 1 ft. |
| Drift space | (00) | 2 ft. |

Cell structure

(QD) 0 (B( 0 (B) 00

(QF) 0 (B) 0 (B) 00

Cell length 28 ft.

B. Short straight

| | | |
|---|---|---|
| Drift space | (SS) | 6.90 ft |
| Drift space | (S1) | 3.40 ft. |
| Drift space | (S2) | 6.56 ft. |
| Drift space | (S3) | 5.77 ft. |

C. Long Straight

| | | |
|---|---|---|
| Drift space | (LS) | 31.80 ft. |
| Drift space | (L1) | 2.00 ft. |
| Drift space | (L2) | 2.62 ft. |
| Drift space | (L3) | 12.00 ft. |

D. Dispersion supressor

| | | |
|---|---|---|
| Drift space | (D1) | 1.10 ft. |
| Drift space | (D2) | 6.90 ft. |

E. Quadrant structure (Q)

SS (Q11) S1 (Q10) S2 (B) 0 (Q9) 0 (B) 0 (B)

S3 (QD) 0 (B) 0 (B) 00 (QF) 0 (B) 0 (B)

00 (QD) D1 (B) D2 (QF) D2 (B) D1 (QD) 0 (B)

0 (B) L3 (Q3) L2 (Q2) L1 (Q1) LS

F. Ring structure

Q ($\bar{Q}$) Q ($\bar{Q}$)

Length of central orbit 203.2296 m

666.76 ft.

## 4. Aperture and Acceptance

Nominal vacuum chamber aperture

$a_H = \pm 89$ mm

$a_V = \pm 25$ mm

sagitta 21.8 mm

available aperture $a_H = \pm 78$ mm

Lattice functions

| | Maxima | In dipole | L.S. | S.S. |
|---|---|---|---|---|
| $\beta_H$ | 48.23 m | 19.50 m | 12.93 m | 10.37 m |
| $\beta_V$ | 19.44 | 13.25 | 10.11 | 11.48 |
| $\eta_H$ | 3.65 | 3.55 | 0.06 | 3.51 |

Acceptance (using beam size in dipoles)

$a_V = \pm 25$ mm  $A_V = 47\ \pi$ mm-mrad

$a_H = \pm 78$ mm  $A_H = 40\ \pi$ mm-mrad

$\Delta p/p)$beam $= \pm 0.25\%$

$\Delta p/p$(beam-to-beam) 2.37%

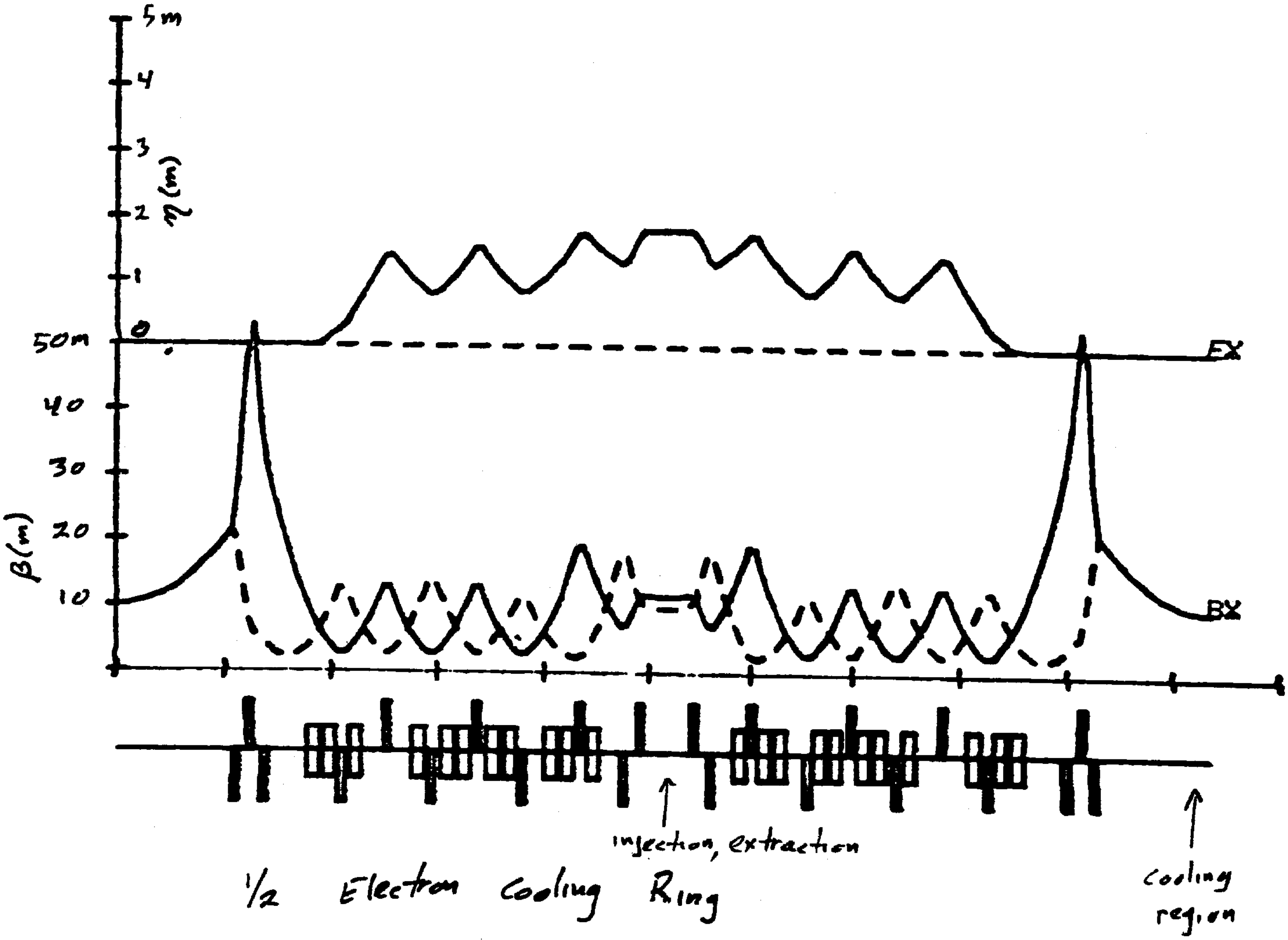
(This is the acceptance for two beams as given with a separation of 10 mm at an injection kicker.)

## 5. Beam angles in electron cooling long straight section

$\Theta_{11} = \sqrt{\varepsilon/\pi\beta^*\ \mathrm{LS}}$  $\Theta_H = 1.76$ mrad

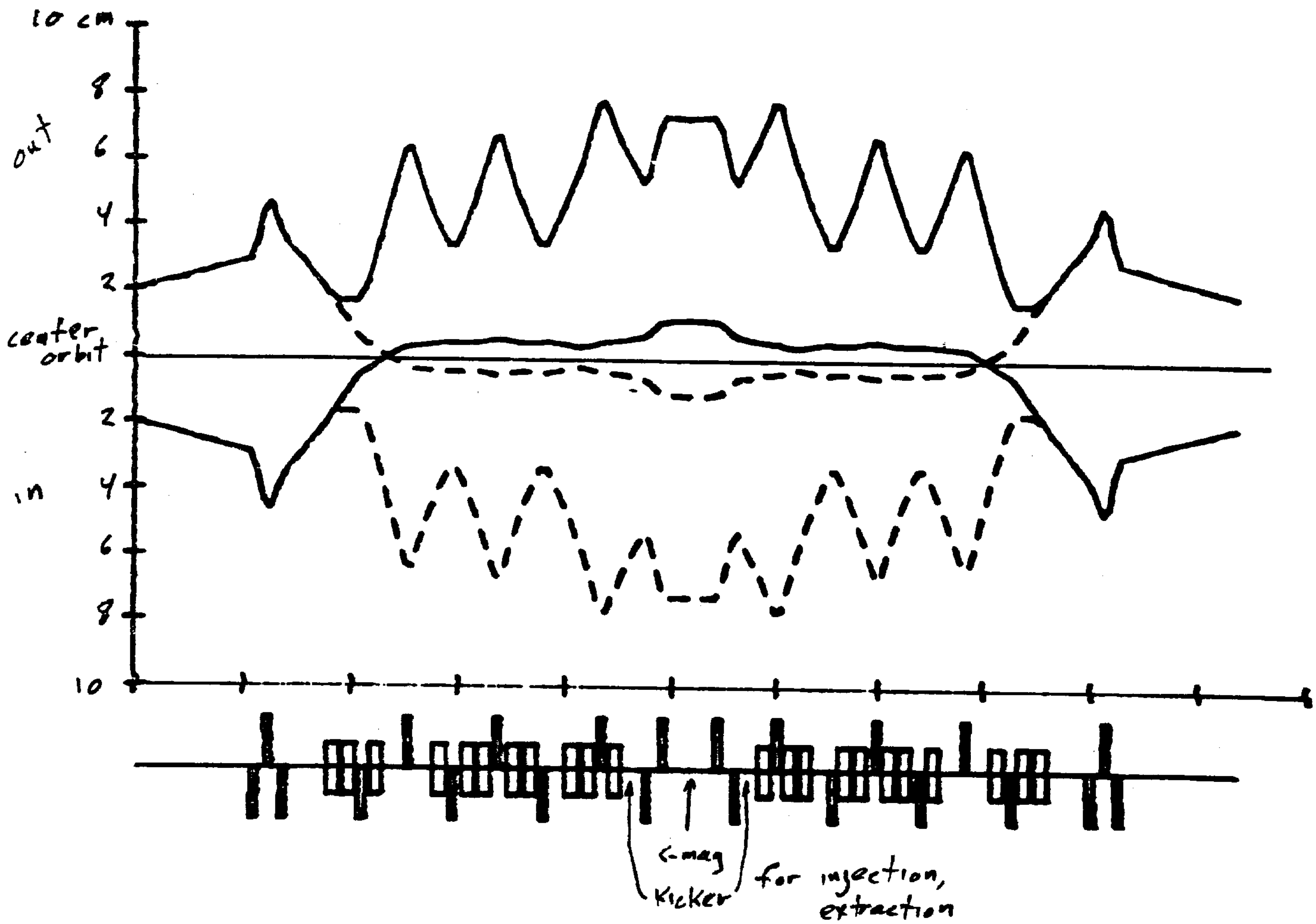
$\Theta_\perp \sim \gamma\ \Delta p/p$  $\Theta_V = 2.17$ mrad

$\Theta_. = 6$ mrad $-$ 10 mrad




1/2 Electron Cooling Ring

Fig. 1




Electron Cooling Ring

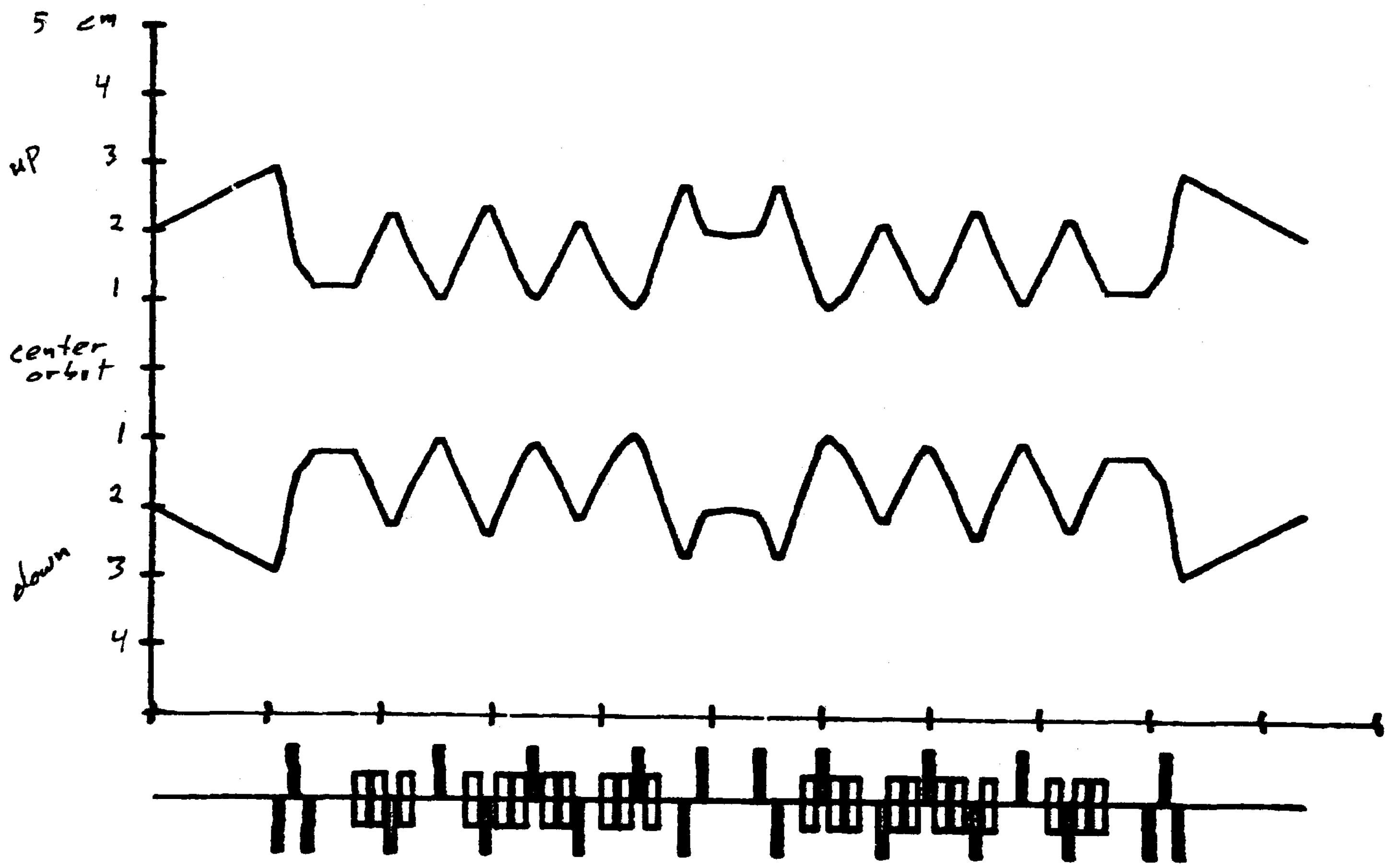
Horizontal aperture

Fig. 2

$\epsilon_H = 40\pi$ mm-mrad

$\Delta P/p = 0.5\%$

2.37 % $\Delta P/p$ between beams.




Electron Cooling Ring
Vertical aperture

$\epsilon_v = 40\pi$ mm-mrad

Fig. 3